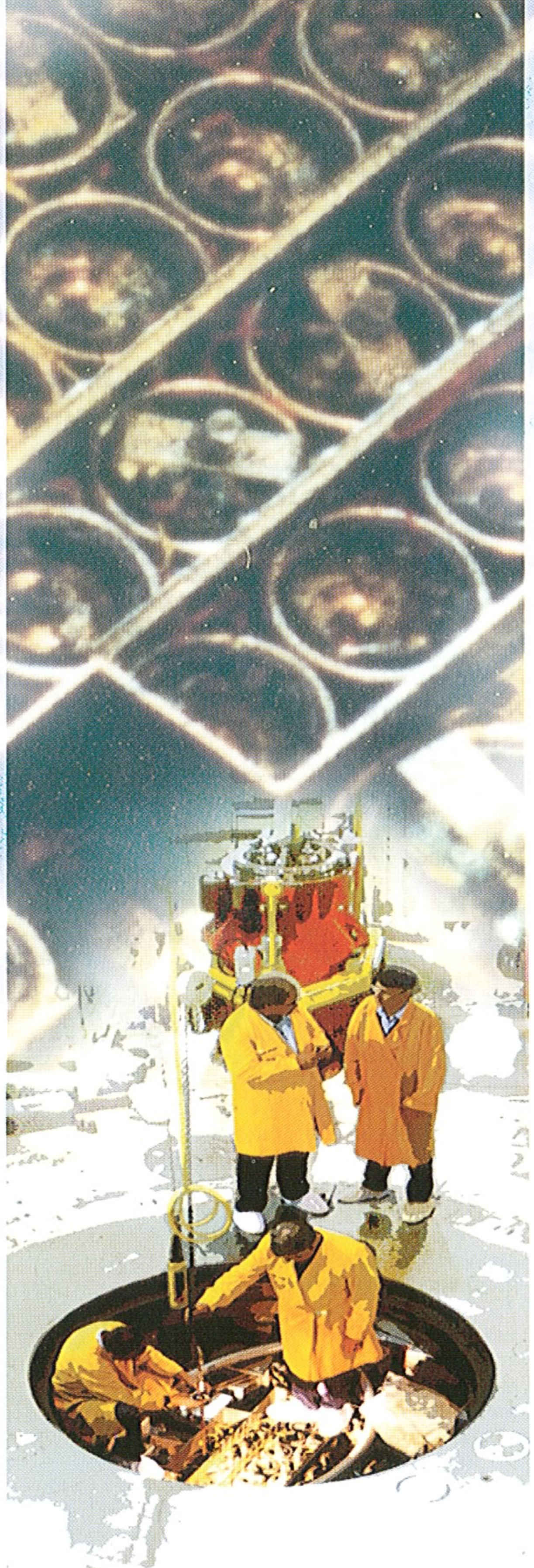


Australia's only research reactor is operated by ANSTO, the Australian Nuclear Science and Technology Organisation. It is located at the Lucas Heights Science and Technology Centre, about 35 kilometres south-west of the centre of Sydney.

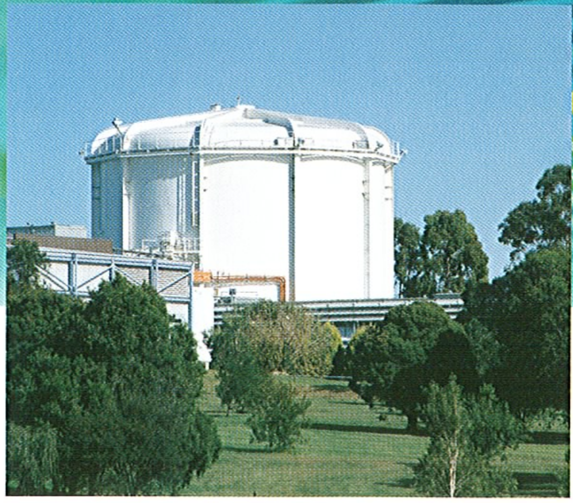
The reactor has operated safely since 1958. It is the foundation of Australia's nuclear medicine capability. It is also used in research into new materials, to irradiate silicon used in computer chips and to produce materials used in environmental management, agriculture, industry and minerals exploration.

The research reactor is a valuable facility used by researchers and students from universities in Australia and New Zealand.

Research Reactor

ansto

SPLITTING ATOMS SAFELY



WHAT IS A RESEARCH REACTOR?

A research reactor is a structure in which a fission (splitting the atom) chain reaction can be maintained and controlled.

Most atoms are stable, but there are some that occur naturally and are unstable and therefore radioactive (they emit radioactive energy in an attempt to reach a state of stability). Uranium-235 (U-235) is one of these unstable atoms.

If you bombard a U-235 atom with a neutron, it will split in half and two or three neutrons will fly off in other directions. Splitting the atom is called 'fission'. If the free neutrons can be controlled so that they hit the next atom and then the next, the process becomes a chain reaction. This is what occurs in a nuclear reactor.

Maintaining and controlling the chain reaction

When the U-235 atom is split, the free neutrons travel away at very high speeds (16,000 km a second). The neutrons have to be slowed to speeds of 1.6 km a second if they are to split further U-235 atoms and produce a chain reaction.

One way of slowing the neutrons quickly is by forcing them to pass through 'heavy water'- water made from deuterium and oxygen. In our reactor, this is achieved by having the uranium fuel elements immersed in a tank of heavy water, which also acts as a cooling system for the fuel elements. Just under half a tonne of heavy water is pumped through the core every second.

Safety around the reactor's core

1. The core of the reactor, which contains the fuel elements, is at the centre of a 2 m diameter aluminium tank almost filled with heavy water.
2. This aluminium tank is enclosed in yet another tank, this time made of steel, which is packed with 57 cm of graphite.
3. This steel tank is inside another steel tank, which is filled with 10 cm of lead.
4. All of this is encased in a 1.5 m thick shield of especially dense concrete. This absorbs any remaining neutrons and radiation, permitting people to work safely close to the reactor.

Refer to numbers on diagram opposite.

The whole reactor is housed in a containment building of steel.

As a further safety measure, the air in the containment building is maintained at just below normal atmospheric pressure. This ensures that if there is an escape of radioactivity from the reactor and the containment building is breached, air will flow inwards, not outwards, thus slowing the flow of any radioactivity to the external environment.

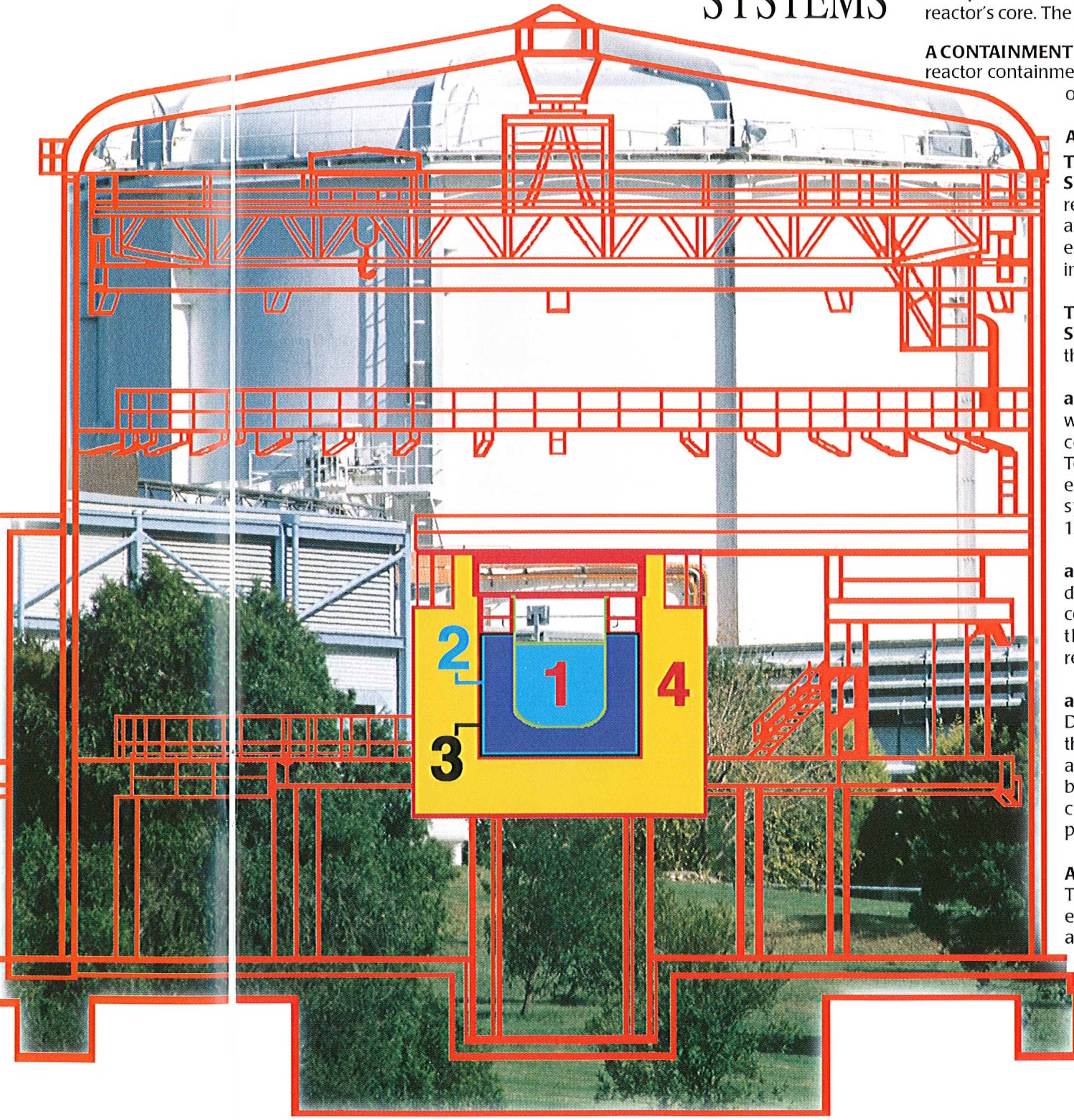
At all times all air entering and leaving the containment building is filtered. Air leaving the building is also monitored for radioactivity.

People leaving the building are also checked at monitoring stations for traces of radioactivity.

The external ANSTO supervisory body, the Nuclear Safety Bureau, believes there could be no circumstances arising at the reactor that would affect the community. However, in the event of an unplanned incident while it is operating, a multi-layered safety system comes into action immediately.

DESIGN

ACTIVE SAFETY SYSTEMS



This multi-layered active safety system includes:

AN EMERGENCY CORE COOLING SYSTEM, designed to protect the core of the reactor from damage if coolant is lost. Two independent pump systems are automatically activated if sensors detect a drop in the level of the heavy water coolant in the reactor's core. The pumps provide coolant to the core

A CONTAINMENT ISOLATION SYSTEM that seals the reactor containment building if there is a release of radioactivity within the building

A SAFETY SYSTEM LINKED TO THE HIFAR ELECTRICAL POWER SUPPLY. If supply is interrupted, the reactor shuts down automatically and backup diesel generators power essential instrumentation and cooling systems

THE REACTOR PROTECTION SIGNAL SYSTEM, which operates at three levels:

a complete shutdown system, which drops two safety rods and six coarse control arms by gravity. Total shutdown of the reactor, either by manual or automatic systems, can be achieved in 1.2 seconds

a restricted trip system, which shuts down the reactor by dropping six coarse control arms by gravity into the core, stopping the chain reaction

a control reversal system
Designed to shut down the reactor, this also drives the coarse control arms that are moved vertically between the fuel elements in the core, thus determining reactor power

A SPACE CONDITIONING SYSTEM. This is made up of three independent systems that control humidity and temperature in the reactor containment building during normal operations. In the event of an accident, these systems reduce air pressure inside the containment building.

SERVICES

INDUSTRY AND ENVIRONMENT

ANSTO's capabilities assist industry and improve environmental management.

To help safeguard Australia's valuable fruit industry, ANSTO uses small doses of radiation to sterilise hundreds of millions of Queensland fruit flies each year. Released into wild fruit fly population, they become a powerful and environmentally benign population control.

In industry, ANSTO radioisotopes are used in non-destructive testing of, for example, pipeline welds. They are used extensively in process controls in a wide range of industries, such as plastics, steel, concrete and minerals concentrating, where levels and densities of materials must be known precisely.

The reactor is also used to test new extraction processes for delivering greater efficiency and environmentally cleaner processing technologies for Australia's minerals industries. It is also used to analyse more than 25,000 samples a year for minerals explorers.

In environmental management, materials from the reactor are used both in Australia and the Asia-Pacific region to trace the movement of pollutants, such as sewage, in our oceans and waterways. In addition, they are used to measure the uptake of both nutrients and pollutants by plants and other living organisms.

They also assist authorities to track and forecast siltation in estuaries, to estimate the effects of coastal development and to manage the effects of dredging.

A key research question being addressed by ANSTO using radioisotopes is 'what is the impact of humans on the rates and mechanisms of key environmental processes in the marine environment?'

ANSTO has also agreed to apply its capabilities to work with its local community to understand specific environmental processes on Sutherland Shire's Kurnell peninsula.

MAKING NUCLEAR MEDICINES

More than 430,000 doses of nuclear medicine are administered to Australians each year. Usage is doubling each five years. Most Australians can expect one in their lifetime.

The raw materials for most nuclear medicines used in Australia come from two sources: the reactor at Lucas Heights and ANSTO's National Medical Cyclotron, which is located at Sydney's Royal Prince Alfred Hospital, Camperdown.

The difference between diagnosis using nuclear medicine and diagnosis using X-rays is that X-rays examine the body's structure, while nuclear medicine produces information on the functions of the body.

Most radiopharmaceuticals emit gamma rays. After being given by injection, inhalation or orally, the gamma rays are emitted from within the body and detected by a gamma camera, which can view organs from many different angles. ANSTO radiopharmaceuticals are despatched daily from Lucas Heights to customers throughout Australia, New Zealand and South-East Asia.

SILICON IRRADIATION

ANSTO is one of the world's major suppliers of irradiated silicon, which is used in advanced electronics applications.

Large single crystals of silicon made in Japan are irradiated in the research reactor for specific periods of time. Irradiation changes one in 1000 million atoms of the silicon-30 in the ingot to silicon-31. After a few hours the silicon-31 decays to phosphorus-31, which changes the electrical resistivity of the silicon. This process, known as neutron transmutation doping, produces silicon with electrical properties superior to those produced by conventional chemical doping techniques.

After a cooling period during which the radioactive material in the ingot decays, the silicon is returned to Japan for use in silicon chip manufacturing.

The ANSTO research vessel *Imara* off Potter Point.

RESEARCH

REACTOR-BASED RESEARCH ACTIVITIES

The research reactor provides scientists and researchers with research facilities unique in Australia. These are attached to some of the 58 blind-sided tubes that are positioned vertically and horizontally around it.

The major research facilities are for neutron scattering. The facilities are used not only by ANSTO, but by students and researchers from 38 universities throughout Australia and New Zealand, and by other groups from research and industrial organisations.

ANSTO provides the university access through the Australian Institute for Nuclear Science and Engineering (AINSE). An AINSE study shows that more than 10% of Australian Doctors of Philosophy in the physical and materials sciences fields have used ANSTO's reactor facilities.

A range of instruments are used for research into the structure and composition of materials. Samples can be studied at different temperatures, pressures and magnetic fields. The range of materials studied is wide and includes organics, organometallic ceramics, magnetic materials, metal hydrides, minerals and biological materials.

In recent years, materials studied have included:

- the giant carbon molecules, 'bucky balls', and related compounds, for which many novel uses have been predicted
- a variety of high temperature superconductors, which are now being used in a new range of superconducting magnetic applications
- multiphase ceramics with intriguing strength-phase relations
- fuel cell materials with especially designed electrical properties.

The reactor also has research facilities for irradiation. Rigs allow materials to be placed close to its core, where radiation levels (both gamma and neutron) are extremely high. This enables researchers to study the effects of radiation on materials that may have uses in medicine or industry. Some positions are used to perform elemental analysis of materials with high neutron capture cross sections, such as uranium bearing minerals, and to analyse forensic samples.

OPERATION

OPERATING AND MAINTAINING THE REACTOR

The reactor operates on a 28-day cycle consisting of 24 days of around the clock operation followed by a four-day shutdown for refuelling, inspections, testing and maintenance. The heavy water plant room, which houses the primary cooling system for the reactor, and the area beneath the reactor's top plate, are accessible only when it is shut down.

Every four years the reactor is closed for an extended period of around 10 weeks for an extensive program of inspections that can only be made when all the reactor's fuel and heavy water coolant have been removed. Detailed inspections are made of the primary cooling circuit, integrity testing is carried out on the aluminium tank that encloses the fuel elements, and checks are made of all plant items not accessible at normal shutdowns.

The last extended shutdown occurred in September-November 1995. The outcomes included:

* detailed visual and ultrasonic inspection of the reactor's aluminium tank. The tank showed no significant deterioration and was passed by the Nuclear Safety Bureau as being safe to continue in service

* replacement of major components, some of which had completed 37 years of service, in the secondary cooling system

* replacement of the centre fuel element temperature indication system

* extensive maintenance of the containment isolation system, which, in the event of an accident, automatically seals all ventilation ducts in the reactor containment building.

FUEL

RESEARCH REACTORS, POWER REACTORS

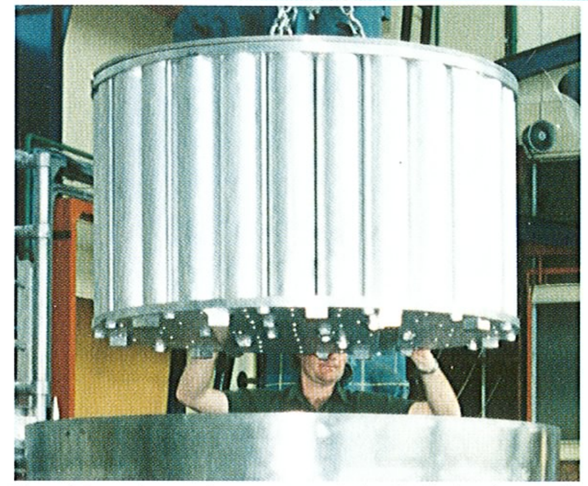
The splitting of an atom, or fission, has two effects - the release of large quantities of energy as heat and the release of two or three neutrons. Both effects are valuable.

A power reactor aims to maximise the amount of heat produced so that water can be turned into steam to rotate turbines and generate electricity. About 17% of the world's electricity needs are met in this way.

There are no power reactors in Australia. ANSTO's is a research reactor and only a fraction of the size of a typical power reactor (see table below).

When most people think of a reactor, they picture the power reactor at Chernobyl. In the table below we have used this RBMK reactor in a comparison between a power reactor and the ANSTO research reactor.

Reactor characteristics	RBMK	ANSTO Reactor
Type	Power generating	Research
Uranium fuel load	190 tonnes	7 kilograms
Operating pressure	1000 lbs per sq. inch	Unpressurised
Operating temp.	284°C	51°C
Heat output (thermal)	3000 megawatts	10 megawatts
Moderator	Graphite	Heavy water
Containment bld.	No	Yes. Total steel enclosure
Core dimensions	7 metres high, 11.8 metres diameter	0.6 metres high, 0.9 metres diameter



The picture above shows an empty basket being lowered into a fuel element transport flask.

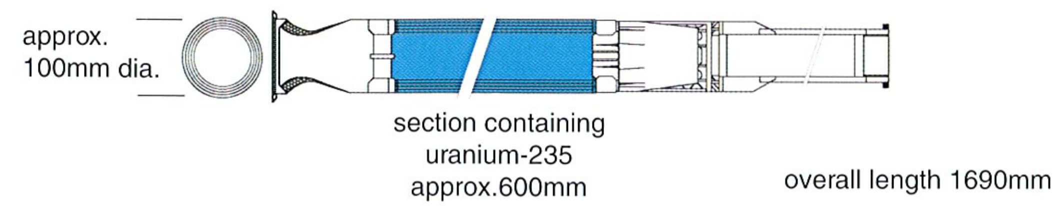
WHAT FUELS THE REACTOR ?

The reactor is powered by 25 fuel elements containing enriched uranium. Located 15.7 cm apart in the reactor core, each element is a hollow aluminium cylinder containing four inner cylinders, one inside another (see diagram). The inner cylinders are made of an alloy of aluminium and enriched uranium, clad with aluminium. The aluminium cladding protects the uranium alloy from corrosion and prevents fission products contaminating the heavy water coolant, which is pumped through the reactor core at the rate of about half a tonne per second.

Each fuel element can be used in the reactor for about 7 - 8 months before it becomes inefficient at producing neutrons and has to be replaced. Such replacements are made during the four days each month that it is shut down for maintenance. On average, about three fuel elements are replaced each month, or about 38 each year.

Lead shielded containers called flasks, each weighing up to 19 tonnes, are used to safely insert and remove new or depleted fuel elements from the reactor. Each element weighs about 6 kg, contains 170 grams of U-235 and costs about $30,000.

ANSTO Fuel Element



MANAGING SPENT REACTOR FUEL

ANSTO's reactor generates about 38 spent fuel elements a year. The management of the elements must conform with stringent international standards.

Spent fuel elements are removed from the reactor in a heavily shielded transport flask. They are placed in a spent fuel storage tank in the reactor containment building, where they are cooled in demineralised water for not less than three months.

The spent fuel elements are then moved to demineralised water ponds in an adjoining building where they are cropped, underwater, to the 600 mm section containing their remaining uranium and associated fission waste products. The operation is carried out in the ponds because the demineralised water absorbs radiation.

Some spent elements are stored in racks in these ponds (water is an excellent shield against radiation) or placed in dry, below ground storage shafts. These 15 metre shafts have been bored into the sandstone bedrock and lined with stainless steel.

When spent fuel elements have been placed in them, the shafts are filled with an inert gas to prevent corrosion of the aluminium sections of the elements. Some elements are also stored in lead and steel transport flasks.

All spent fuel stored at ANSTO is regularly inspected by the International Atomic Energy Agency, an agency of the United Nations, as part of its program of monitoring nuclear materials around the world.

WHO MONITORS ANSTO ?

ANSTO is answerable to a number of independent, external organisations in regard to the safety of its activities.

The International Atomic Energy Agency makes both regular, quarterly inspections and random, unannounced inspections to ensure that ANSTO is meeting its obligations in regard to the security of its nuclear materials. These obligations are also monitored by the Australian Safeguards Office, which is part of the Department of Foreign Affairs and Trade.

The Australian Radiation Laboratory, which is based in Melbourne, audits the measurement of all gaseous radioactive discharges from ANSTO. It reports to the Federal Parliament.

The Nuclear Safety Bureau, situated in the Sydney suburb of Miranda, licenses ANSTO's nuclear plant and has wide powers in regard to its operation. It also reports to the Federal Parliament.

The Safety Review Committee, another independent body that reports to the Federal Government, has a specific brief to oversee the safety of ANSTO's activities. This organisation includes a representative of the local Sutherland Shire Council.

ANSTO is also subject to all legislation designed to protect the safety of Commonwealth employees.

More information:

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